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Simulating Plasma, Neutrals, and Photons in the Tokamak Edge Region[1]

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The region of tokamaks and other plasma confinement devices near material surfaces is rich in the number of physical processes occurring simultaneously. In this so-called edge region, plasma temperatures drop precipitously, neutral gas evolved by impinging plasma on material surfaces is ionized, and line-radiation energy loss can become large. Two key issues for fusion reactor development are reducing the particle and radiation heat load on material surfaces to < 5 MW/m^2, and providing adequate pumping of the helium ash from the core D-T fusion reactions. In this talk, an overview is given of the models used to simulate transport in the edge region with an emphasis on the basic physical processes and their interaction. A common modeling issue for all three species - plasma, neutrals, and photons - is that they can have sub-regions with short or long mean-free paths (MFP) compared to gradients. For the lower temperatures of the edge region, the Coulomb collisional MFP is typically short enough that 2-D fluid transport models can be used with classical transport along the magnetic field lines and anomalous or turbulent transport across the field lines. However, kinetic corrections to the usual classical transport coefficients are often important, and hot-particle tails require more detailed kinetic models. The neutral gas evolved from surfaces is described by fluid models or kinetic Monte Carlo models where again there are different region of short and long MFP. The neutrals provide a dominant source of plasma near the surfaces and the plasma in turn can recombine in the volume, providing an extra source of gas. In addition to the dominant hydrogenic gas species, intrinsic impurity gases (typically carbon or beryllium) are evolved from the surfaces, giving rise to substantial line radiation owing to electron-impact excitation and ionization which cools the plasma. Such cooling may be enhanced by controlled injection of impurity gases such as neon or argon. Reabsorption of the resulting photons by the gas can be an important process for high densities, again making the modeling of transport in the transition from short-to-long MFE an important issue. Atomic physicists helping by providing improved rates for hydrogenic and impurity gases in the range of 1 - 100 eV, and to identify recombination mechanisms.

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